BRINGING PERSONALIZED TIES BACK IN: Their Added Value for Biotech Entrepreneurs and Venture Capitalists Interorganizational Networks

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Using a unique data set collected in France among biotech entrepreneurs and their venture capital investors (VCs), we measure the added value of personal relationships at the interorganizational level. Our analyses show that when two entrepreneurs share a personal collaboration tie or a personal friendship tie with a VC investor, the probability of having an advice tie and thus exchange tacit knowledge increases significantly. We confirm the importance of this kind of social embeddedness in the biotech industry where personalized ties—as opposed to institutional and contractual relationships—at the interorganizational level had not yet been examined systematically. Our results suggest that strategies of personalization of exchanges are vital for interorganizational learning. These strategies help entrepreneurs to access resources, participate in knowledge building, and co-orientate activities in this sector.

Personalization of economic interactions is at the heart of contemporary renewal of economic sociology. Granovetter's work on the strength of weak ties (1973) and social embeddedness of market exchanges (1985) initiated a large number of studies showing the effect of interindividual relationships on economic activities. In this article, we apply this approach to the study of the biotech industry. This sector has been widely examined in social sciences from the perspective of contractual ties but rarely from the perspective of personalized ties. This is surprising because existing research, while assuming the existence of interindividual relationships and considering such ties to be very important, observe contractual ties exclusively.

We rely on results obtained at the intraorganizational level in the study of advice networks, multiplex networks, and the collective learning process in order to develop a model of analysis to test the added value of personal relationships in that sector. We use a unique data set on collaboration, advice, and friendship ties that biotech entrepreneurs maintain with each other and with their investors in venture capital (VC). Our results provide support to the idea that personalized ties add value for collective learning in that

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milieu. In particular, we show that personalized ties shared with VCs facilitate transfers of knowledge among entrepreneurs and thus, their capacity to share tacit knowledge at the interorganizational level.

THEORY

From Strength of Ties to Interpersonal Relationships

Following Granovetter's work on the strength of weak ties (1973), a wide literature has focused on the type and value of resources that actors can access through social ties (Granovetter 1983). This very large body of work tends to show that weak ties allow access to nonredundant information, while strong ties generate a context of reliable nonmarket exchanges that stabilizes norms and collective identities. Strength of ties has been measured by frequency, multiplexity, intensity, or type of relationship among actors. This set of indicators is included in Granovetter's definition: "the strength of a tie is a (probably linear) combination of the amount of time, the emotional intensity, the intimacy (mutual confiding), and the reciprocal services which characterize the tie" (Granovetter 1973:1361). Regardless of technical specificities of measurement of these different dimensions, the value of this notion of *strength of a tie* is based on the idea that the more personalized the tie among individuals, the stronger it is.

At the intraorganizational level, Krackhardt's (1992) study on the importance of strong ties shows how friendship ties, which he calls *philos* and which he defines based on a very precise protocol, are particularly important in major organizational changes. In situations of uncertainty, when interdependencies among actors, the terms of their exchanges, and the status games that allow them to make decisions are questioned, it is their *strongly personalized* ties that create the trust and conditions that are necessary for actors' involvement (Lincoln and Miller 1979; Lin, Ensel, and Vaughn 1981; Friedkin 1982; Granovetter 1983; Krackhardt 1992; Bian 1997; Jack 2005). Brass (1984) showed at the intraorganizational level that friendship ties are less decisive than communication ties for influence purposes, but in contrast to Krackhardt's (1992) setting, the context of his study is not characterized by a situation of strong institutional uncertainty.

At the interorganizational level, a limited number of studies have shown the effect of systematic interpersonal ties between organizations on economic activities (Saxenian 1990; Uzzi 1997; Cohen and Fields 1999; Ingram and Roberts 2000; McDonald and Westphal 2003). Ingram and Roberts (2000) suggested that friendship ties reinforce collaboration, improve the quality of exchanges, and mitigate competition among executives in the hotel industry in Sidney. In the same vein, work by Lazega et al. (2004, 2008) on exchange networks between cancer research laboratories in France showed that personalization of ties among scientists facilitates the emergence of social niches in which competition is temporarily mitigated and performance is increased for participating individuals.

Interpersonal Relationships between Organizations: The Case of the Biotech Industry

In spite of these rare exceptions, the study of interorganizational relationships is largely dominated by a contractual approach to exchanges (concerning the biotech industry, see, for example, Baum, Calabrese, and Silverman 2000; Zucker and Darby 2001; Filiou 2005; Powell et al. 2005; Salman and Saives 2005). This rather "purely economic" approach contradicts the theoretical and methodological context that stresses the importance of social networks for the emergence, development, performance, and innovation capacities of organizations.

In the study of *knowledge intensive industries* such as the biotech industry, the absence of individuals and of their personalized ties underestimates two of the main results of the literature on the strength of ties. First, as signaled by Powell and Grodal (2005), strong ties are particularly efficient in the exchange of complex information. In the biotech industry, the often tacit and weakly codified character of knowledge that is necessary for the timely development of new products justifies a stronger preoccupation for interpersonal ties that help with the transfer of this knowledge. Second, strong ties have been described as particularly useful in situations of uncertainty (Granovetter 1983; Krackhardt 1992): financial and regulatory constraints, as well as scientific and industrial risks that characterize the biotech industry create a context that is sufficiently uncertain to raise interest in interpersonal social niche strategies that are used by entrepreneurs to reduce this uncertainty (Lazega and Mounier 2002).

Paradoxically, the importance of interpersonal relationships in interorganizational exchanges in the biotech industry is often acknowledged by the scientific community itself (see, for example, Pisano 1991; Powell, Koput, and Smith-Doerr 1996; Corolleur, Mangematin, and Torre 2003; Niosi 2003; Casper 2007). Nevertheless, with rare exceptions (Kreiner and Schultz 1993; Grossetti and Barthe 2008), the great majority of studies in this sector map contractual relationships and "assume" the existence of interpersonal relationships. This consensus is explicitly formulated by Powell and Grodal (2005:71): "There is a strong sense among researchers that informal relations undergird formal ties." Powell et al. (1996) argued that in the life sciences, "beneath most formal ties lies a sea of informal ties." It is therefore important to further explore this issue at the interorganizational level in the biotech industry.

Knowledge Transfers among Biotech Entrepreneurs

One way to start taking into account systematically the interpersonal relationships at the interorganizational level is to follow what has been performed at the intraorganizational (Cook 1977; Lazega and Mounier 2002). At this level, many studies have shown that collective construction and exchange of knowledge can be measured through advice ties (see, for example, Krackhardt 1987; Ibarra 1992; Lazega 1995; Lazega and Van Duijn 1997; Podolny and Baron 1997; Cross, Borgatti, and Parker 2001; Sparrowe et al. 2001; Hansen 2002; Borgatti and Cross 2003; Gibbons 2004). At the interorganizational level, Pina-Stranger and Lazega (2010) showed in their study of advice ties among executives in the French biotech industry the existence of a hierarchical exchange system in which

different epistemic communities coexist. These communities are characterized by stronger cohesion both in reciprocity and in multiplexity of affiliations maintained by their members (Pina-Stranger 2009, 2010). In spite of these results, the hypothesis of the added value of interpersonal ties for access to resources in comparison with formal interorganizational relationships is not yet truly tested because most companies to which these individual entrepreneurs belong do not maintain formal and contractual relationships with one another. As a result, it is not possible to compare directly the outcome of an informal relationship between two companies with the outcome of a formal relationship between two companies; if such a comparison was possible, it would allow us to clearly establish the value added by each type of relationship.

HYPOTHESES

Do Interpersonal Relationships Add Value?

Based on work on the strength of strong ties that stresses the importance of this type of relationships in uncertain contexts and for the transfer of complex information, and based on the studies of advice networks at the intraorganizational and interorganizational levels, we argue that at the interorganizational level, interpersonal relationships add value compared with "decoupled" relationships—to use the terminology of Grossetti and Bès (2001). However, the absence of formal ties among biotech firms in France does not allow for testing directly the added value of these informal exchanges for access to resources or for better economic results. In order to operationalize our hypothesis on the added value of interpersonal ties, we explore the relationships between biotech companies and VC firms. Relationships between these two kinds of actors provide a favorable empirical setting for the measurement of specific effects of personalization of ties because formal contractualization of financial participation is systematic.

Our hypotheses focus on the effect of two types of relationships: collaboration ties and friendship ties. Lazega and Pattison's (1999) study of multiplexity of exchanges has shown that both types of ties have a separate effect, through transitivity, on access to advice. This means that when two actors share a friendship tie or a collaboration tie with a third party, the probability that they will establish an advice tie is high. Following this result at the intraorganizational level, we explore in our analyses whether two biotech executives sharing such ties with the same VCs tend to exchange advice with each other. We specify the level of personalization that relationships must reach to facilitate this transitivity. Thus, we transport the issue of multiplexity and transitivity in interpersonal ties toward contexts where all ties are exclusively interorganizational.

Collaboration Ties

Collaboration ties among biotech companies and VC firms begin when the latter decide to invest in the former, thus becoming part of its ownership. Therefore, most often, the VC firm is represented by one of its experts in the board of the biotech firm. The board thus structures the collaboration between entrepreneurs and investors on a legal and contractual level: board members vote on strategic decisions that the company makes.
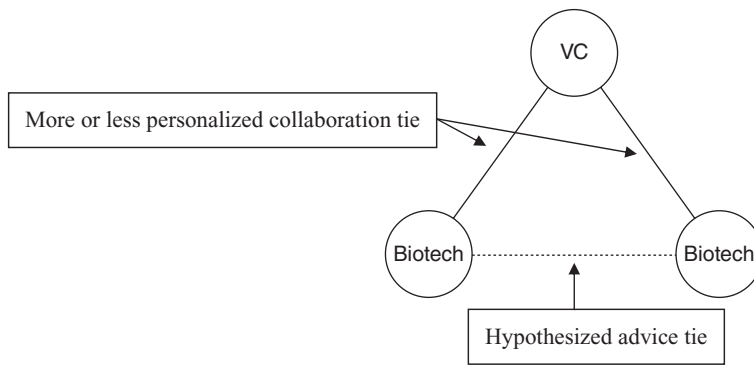
FIGURE 1. Expected Effect of Shared Collaboration Ties with a Venture Capital on Advice Exchange between Biotech Entrepreneurs.

The companies belonging to the portfolio of a VC investor may have the same expert in their board or they may have a different expert. If they share the same expert, the relationship they share with a VC is more personalized than if they do not share the same expert, in other words, if they just have the same VC firm in their board. Based on previous theory and the characteristics of this context, we thus derive the following hypothesis on the added value of personalization of ties applied to collaboration ties:

> Hypothesis 1:   Entrepreneurs sharing a personal collaboration tie with a VC have a higher probability of exchanging knowledge with one another through an advice tie than entrepreneurs who do not share such a personalized collaboration tie (Figure 1).

Friendship Ties

In spite of sometimes tense interactions (Wasserman 2008), a number of entrepreneurs and VC investors maintain friendship ties. These relationships emerge in various kinds of social circles, mainly from shared university education, past and present collaborations, or repeated meetings in specialized conferences, professional associations, or governmental expert committees. In the French context, biotech executives and VC investors have opportunities to meet on a monthly basis. We use this context to explore the effect of personalization of relationships through friendship ties. To do this, we compare the sharing of a friendship tie with a VC with the simple sharing of a common investor (who may or may not be a member of the board). We thus derive the following hypothesis:

> Hypothesis 2:   Entrepreneurs who share a friendship tie with a VC investor have a higher probability of exchanging knowledge through an advice tie than entrepreneurs who do not share a friendship tie with a VC investor (Figure 2).

Ethnographic Evidence and Alternative Hypotheses

These hypotheses are based on three assumptions that need to be made explicit and justified. First, they assume that biotech entrepreneurs design strategies to access their
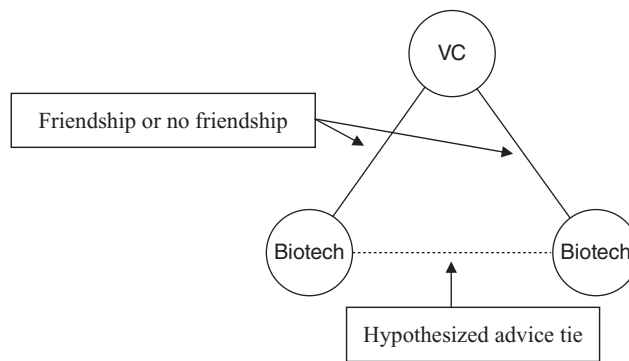
FIGURE 2. Expected Effect of Shared Friendship Ties with a Venture Capital on Advice Exchange between Biotech Entrepreneurs.

competitors' advice. Second, our hypotheses presuppose that VCs are willing and able to facilitate the emergence of ties among biotech entrepreneurs. Third, they presuppose that transitivity at the interorganizational level is complementary to other social processes (such as professional affiliations and geographical colocation) that explain informal exchanges of knowledge among entrepreneurs.

Interpersonal Exchanges among Competitor Peers in the Biotech Industry
Biotech entrepreneurs compete for access to multiples resources: public funding, a place in industrial clusters, or private investment. The model of technology transfer in this industry is characterized by a division of work between public research centers, investors, and large pharmaceutical companies. This model puts all biotech companies in a relatively similar position (Pisano 2006). They share the same partners, the same public interlocutors, and the same types of constraints and difficulties. When an entrepreneur must access a piece of information or inquire about how to obtain it, it is often entrepreneurs running competing companies who are in the best position to provide appropriate help (Lazega 2009). Therefore, informal knowledge exchange relationships are described by these entrepreneurs themselves as vital for their survival and success.

Knowledge exchanged by these entrepreneurs is about the main activities of these firms. They exchange information about the management of their respective companies. They discuss interaction with public authorities, notably fiscal authorities, with which they must manage access to public funding and tax reductions, and with health authorities regulating the development of therapeutic products. The organization and operations of these public authorities change constantly because they are faced with strong demands from politicians, patients associations, and other companies to facilitate the development of the biotech sector. This changing environment gives value to new and sometimes temporary managerial know-how that entrepreneurs acquire in their work.

Entrepreneurs also exchange knowledge about development of therapeutic products. Here, we can mainly identify three epistemic domains: scientific, financial, and

industrial kinds of knowledge. In the milieu of biotech entrepreneurs, certain actors are considered experts in one or several such domains. Therefore, their peers seek their advice. This allows them to strengthen their position and control the choice of appropriate knowledge. Entrepreneurs who do not benefit from this level of epistemic status have an interest in participating in this exchange system if they do not want to be isolated. Participating in the exchange of these different types of knowledge allows entrepreneurs to lower the risks associated with the activities of their company. Information that they can access provides opportunities to improve their performance, anticipate administrative and industrial changes, and participate in collective knowledge building. Relational activity and advice seeking from one's peers does not only characterize entrepreneurs with low epistemic status, opinion leaders in this milieu also seek advice from their peers if they want to keep their status and benefit from it (Pina-Stranger and Lazega 2010).

The Role of VCs

The business model of biotech companies is most often based on a partnership with VCs. This type of investor is present in industries in which uncertainty and information asymmetries among the various actors involved are high (Sahlman 1990; Amit, Brander, and Zott 1998; Gompers et al. 1998). It is about this information asymmetry that VCs claim that they play an expert role in the evaluation and support of biotech companies (Zacharakis and Shepherd 2001). In effect, beyond the money invested, the relationships between VCs and entrepreneurs in the latter's board is supposed to provide these companies with other resources: management and strategic advice (Gorman and Sahlman 1990; Gifford 1997; Busenitz, Fiet, and Moesel 2004), credibility with potential partners and clients (Hsu 2004; Nahata 2008), and contacts (Rosenstein 1988; Rosenstein et al. 1993).

The predominant business model in the biotech sector puts VCs in a broker role for the companies in their portfolios. Therefore, one of the main networks that VCs can share with biotech entrepreneurs is composed of other biotech firms and entrepreneurs in which they have also invested. Our hypotheses thus explore the, more or less, personalized relational conditions that allow biotech entrepreneurs to benefit from the network of other entrepreneurs provided by their VCs.

As far as entrepreneurial strategies are concerned, our hypotheses explore the ways in which entrepreneurs manage their relationships with their competitors. In effect, companies belonging to the same portfolio of a VC compete directly for access to resources that their common VC can provide. Here is an excerpt from an interview with one of these entrepreneurs who describes the competition between companies belonging to the same portfolio:

> At the beginning, the VC told us "rather than reinventing the wheel, call the financial manager [of one of the companies in their portfolio] and he will tell you how he does it." But in fact he gave us very basic practical information, and after that it was over. It's every man for himself [. . .]. After that you are under the impression that there is competition between the companies in that portfolio. If others do not do well, I

will be considered the hero of that portfolio, especially since they are often very close companies. I give you an example. Our company was set up the same year as another company that was working on a close topic. The VCs never brought us together. Just the opposite. It was like each company with its partners. I think the first time we met them was five years after, only because they were in trouble and we were considering a possible merger. So we know them but there is not necessarily a relationship. In fact we learn about the funds they raise in our trade magazine, just like anyone else. (Chief Scientific Officer [CSO], company no. 26)

The relationships between entrepreneurs of the same portfolio are a sensitive matter. The proximity induced by sharing the same VC can harm the knowledge transfer between two entrepreneurs. VCs can, more or less, encourage meetings between entrepreneurs or try to prevent exchanges between them. In this context, we assume that personalization of ties between entrepreneurs and their VCs structure in part the ways in which these direct competitors are managed. More specifically, our hypotheses assume that personalization of ties between VCs and entrepreneurs encourages among the latter a relational behavior that favors knowledge exchange among competitors.

Alternative Hypotheses

Belonging to the same portfolio and the personalization of relations with VCs are not the only mechanisms that create relationships among biotech entrepreneurs. Other elements that have been researched already explain the existence of knowledge exchange relationships among these entrepreneurs.

Work by Higgins and Gulati (2003, 2006) has shown how the sectors of origin of entrepreneurs, especially those coming from the biopharmaceutical sector, affect the capacity of a firm to receive the endorsement of a prestigious investment bank and its investments. This sector also has an effect on the establishment of ties at the interorganizational level. Kim and Higgins's (2007) work on homophily has shown that the professional origin of executives was correlated with the kind of partner with whom their company signs contracts. Following these statements, we have shown that the informal exchange of knowledge between biotech executives also tends to be homophilous and based on past institutional affiliations of entrepreneurs (Pina-Stranger and Lazega 2010). In particular, we have shown that when two entrepreneurs have the same professional origin, the probability that they will create an advice tie with one another is higher than if they do not have this common trait.

The second mechanism that can generate a knowledge exchange tie is related to geographical colocation. In the specific case of the human health sector of the biotech industry, many studies have focused on the "cluster effects" in the production of new scientific knowledge (Saxenian 1994; Audretsch and Stephan 1996; Powell et al. 2002; Stuart and Sorenson 2003; Coenen, Moodysson, and Asheim 2004; Owen-Smith and Powell 2004; Chiesa and Chiaroni 2005; Gertler and Levitte 2005; Chen, Shyu, and Tzeng 2006; Casper 2007; Aharonson, Baum, and Plunket 2008; Gilding 2008). This body of work shows that geographical proximity and the sharing of the same spatial and institutional context increases relational proximity and thus the possibility for entrepreneurs

to exchange tacit knowledge through personal ties. In our work (Pina-Stranger under review), we showed that comembership in a cluster is associated with epistemic proximity. We defined epistemic proximity as consensus concerning the choice of local opinion leaders. At the regional cluster level, entrepreneurs agree to follow the advice of a limited number of opinion leaders despite differences in their professional origins.

Finally, a third mechanism may explain the existence of a knowledge exchange relationship. It is related to the structure of relationships that are present in this milieu. Work by statisticians specialized in network analysis (Snijders et al. 2006; Robins et al. 2007; Snijders et al. 2007) has shown that different types of relational substructures in which actors are embedded change the probability of establishing relationships over time. In advice networks, some regularities have been established (Lazega and Van Duijn 1997; Lazega and Pattison 1999). First, in nonbureaucratic contexts, actors tend to seek advice from the adviser of their adviser. This transitivity effect is part of a centralization process that characterizes such networks. Then, actors are not sought out by the adviser of their adviser. This effect (called negative three cycles) accounts for the hierarchical character of knowledge networks in which actors are not willing to attribute epistemic authority, in other words, the authority to know, to others below them in the status hierarchy or pecking order. Finally, advice networks, in spite of their hierarchical and centralized character, also make room for some reciprocity. This reciprocity is partly related to homophily based on various identity criteria, such as professional or geographical. In that sense, reciprocity represents individual actors' efforts to mitigate the strong constraining effects of status.

These three different mechanisms have allowed researchers to explain in part the existence of a knowledge exchange relationship. They generate hypotheses that compete with the hypotheses that we explore in our current analyses. We suggest that in the context of the biotech industry, personalization of relationships between entrepreneurs and VCs is a complementary mechanism that contributes to understanding the relational and structural conditions in which knowledge exchanges take place at the interorganizational level.

DATA AND METHODOLOGY

Fieldwork

In order to test our hypotheses, we conducted in 2008 a survey with a subpopulation of biotech companies and with their VCs in France. We selected this population based on information available in trade associations, regional clusters, specialized press, and VC sites. Our objective was to collect information on all the French biotech firms active in 2008. We chose to select the firms that work in the human health subfield of the life sciences and that have benefited from public or private investments above €500,000. We thus excluded all the companies that were not "validated by the market," to use indigenous vocabulary, by focusing on firms growing autonomously, in other words,

independent from public research laboratories. We selected exclusively French companies and excluded subsidiaries of large pharmaceutical groups as well as services and consulting firms.

Depending on the level of development of the company, we included between one and four managers of these companies in our data set according to the following criteria: founders; president/general director (chief executive officer); scientific director (CSO), financial director (chief financial officer), and director of operations (chief operating officer). Information collected about these persons focuses on their trajectory and their advice ties with other entrepreneurs and with VCs in France.

At first, the population included 96 firms and 229 managers. We kept redefining the boundaries of our population because we realized during the process of collecting information that some of the firms in our list did not meet the criteria listed earlier. Following this fine-tuning process, our final population included 88 firms and 164 managers. We conducted 125 face-to-face interviews and received 13 questionnaires via e-mail. Information on the 26 actors who did not answer the questionnaire was collected differently. Among the 88 firms of our population, we were unable to interview 10 managers personally, ending up with 11 percent missing data with respect to relational information (outgoing choices).

VC firms in our population are those who have invested in these biotech companies. First, we collected systematic information on the presence of VCs on the board of these companies. Then, we interviewed these VCs and collected information about their trajectory and their advice and friendship ties with other VCs and with the biotech entrepreneurs. This population of VCs is composed of 30 individuals representing 28 VC firms, 20 of which were personally interviewed.

Dependent Variable

Our dependent variable is presence or absence of an advice tie that biotech entrepreneurs in France maintain with one another. We reconstituted this network by asking the entrepreneurs to check the names of people from whom they sought advice. The list of names finally retained corresponded to the 164 managers of the 88 biotech firms of our total population. This list was fine-tuned during the first interviews with help from interviewees who were allowed to include names of entrepreneurs missing in the initial list. We asked them whom they sought out for advice on issues related to the management of their main partners: research centers, VCs, and pharmaceutical companies. We considered questions related to the management of these partners as *proxies* for the three kinds of knowledge mobilized in the development of therapeutic products: scientific, financial, and industrial kinds of knowledge. The advice network examined here aggregates responses across the three types of resources exclusively between organizations. This means that we did not include intraorganizational advice ties in the network analyzed here.

Dyadic Independent Variables

In order to test our hypotheses on the added value of personalization of ties with VCs, we constructed two sets of three dyadic variables for each type of personal relationship.
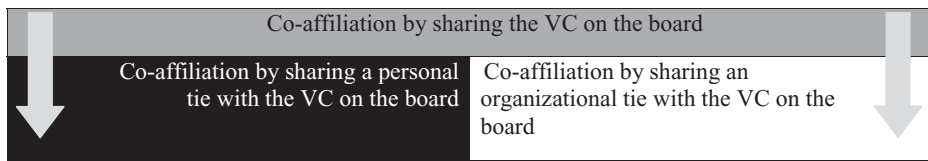
Co-affiliation by sharing the VC on the board	
Co-affiliation by sharing a personal tie with the VC on the board	Co-affiliation by sharing an organizational tie with the VC on the board

FIGURE 3. Link between Dyadic Variables Representing the Type of Collaboration Relationship Shared with Venture Capitals Present on the Board of the Biotech Companies (Gray is the Sum of Black and White).

Dyadic variables are represented by symmetric matrices associating a value with ties that are maintained or in this case, shared, by the actors. These variables have been used to explore the relationship between different types of ties (Gibbons 2004), to represent geographic affiliations and gender homophily (Borgatti and Cross 2003), or to explore the effect of institutional affiliations (Pina-Stranger and Lazega 2010). In our analyses, we used dyadic variables to represent the fact that two entrepreneurs share a similar tie with a third party, in this case, a shared relationship with a VC. These ties were co-affiliations in the sense that two actors were related to a common third party by the same type of tie.

Collaboration Ties

Our hypothesis concerning collaboration ties asserts that if two entrepreneurs share a personal relationship with a VC, the probability that they will exchange advice is higher than if they share an impersonal collaboration relationship with a representative of the VC on their board. To explore this difference, we first created a dyadic variable representing all the pairs of biotech entrepreneurs sharing the same VC in their board in 2008 regardless of whether it is the same person or not (*co-affiliation by sharing a VC in the board*). Then, building on this first variable, we differentiated pairs of entrepreneurs sharing in their board the same *person* representing a VC investment firm (*co-affiliation by sharing a personal tie with the VC in the board*) from those who do not share the same person in their respective board but share a same investor who is represented in their boards by two different persons (*co-affiliation by sharing an organizational tie with the VC in the board*) (Figure 3).

Friendship Ties

Our second hypothesis explores the effect of sharing a friendship tie with a VC on the exchange of advice among entrepreneurs. We compare the effect of this shared friendship tie and the effect of sharing the same VC regardless of the fact that he or she is or is not present in their board. To do this, we first created a dyadic variable representing all the pairs of biotech entrepreneurs sharing a friendship tie with the same VC, while the latter's firm never invested in the company (*same VC friend*). Then, we created another dyadic variable representing all the pairs of biotech entrepreneurs sharing the same VC in the capital of the company but with whom they do not maintain a friendship tie (*same historic VC*). Finally, we represented in a dyadic variable all the
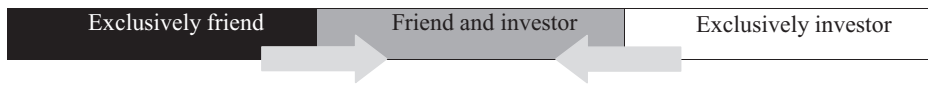
Exclusively friend	Friend and investor	Exclusively investor

FIGURE 4. Link between Dyadic Variables Representing the Degree of Friendship Embeddedness of Relationship Shared with the Venture Capital (Gray Is the Superposition of Black and White).

pairs of entrepreneurs sharing a VC investor in the capital of the company but with whom they also maintain a personal friendship tie (*same VC friend and historic VC*) (Figure 4).

We reconstituted the friendship network by asking the biotech entrepreneurs and the VCs who were the persons with whom they would maintain a relationship even if they radically changed professions and lines of business. This question allows us to limit the extension of our definition of friendship. In our study, friendship ties remain professional ties. They account for persons on whom actors believe that they will be able to count independent of the position that they will occupy in the future. In that sense, friendship here represents interpersonal relationships that have become autonomous relative to current entrepreneurial affiliations but that remain dependent upon a wider professional context.

In the friendship network that we used in these analyses, we considered that a tie exists between ego and alter even if it has not been confirmed by alter. We prefer this more flexible definition of friendship ties over reciprocal relationships to integrate a larger number of actors (reciprocal friendship ties cover 30 percent of all friendship ties observed). The results that we obtained concern therefore a larger number of actors and in particular, they are not limited to the description of the dense, multiplex, and small core of central entrepreneurs and VCs in this *milieu*.

Control Variables

We used two types of control variables. The first variables are structural effects that come attached to the use of exponential random graph models (ERGMs), which we present in the next section. The second type of variables represents two dimensions of the context (*professional origin* and *geographical colocalization*) facilitating knowledge exchange as observed in this population. The particular relational effect that we use with these kinds of control variables is the similarity of attributes of entrepreneurs in selecting advisors (similarity or homophily effect). We present the correlation table for these variables in the Appendix.

Professional Origin

The first control variable concerns the effect of institutional affiliations of biotech entrepreneurs. Following work on the effects of upper echelons on the development of biotech firms (Higgins and Gulati 2003; Gulati and Higgins 2005; Kim and Higgins 2007), we have shown that entrepreneurs sharing the same professional origin exchange more knowledge among themselves than with others (Pina-Stranger and Lazega 2010).

In this variable, entrepreneurs are categorized based on the sector in which they worked prior to working in a biotech company: biopharmaceutical industry (84 actors), public research center (50 actors), and finance (30 actors).

Geographical Colocalization
The second control variable concerns the effect of geographical proximity on exchanges of knowledge. In the French industry, the positive effect of geographical colocalization on the development of companies has been largely proven (about France, see Lemarié, Mangematin, and Torre 2001; Autant-Bernard 2002; Boufaden and Plunket 2005). Results obtained on our population confirm the idea that geographical colocalization facilitates under specific conditions the exchange of knowledge and consequently, the possibilities of coordination and learning of entrepreneurs (Pina-Stranger under review). The variable "cluster" that we use in our analyses thus controls for the effect of geographical colocalization on relational choices in the advice network.

ERGMs for Social Networks
In order to test our hypotheses, we examined the effect of dyadic variables representing co-affiliation on advice seeking and giving behavior using ERGMs (Snijders et al. 2006; Robins et al. 2007; Snijders et al. 2007). These models identify prespecified substructures characterizing the network mainly at the dyadic and triadic levels and use a stochastic approach taking into account unobserved heterogeneity in the data so as to explain the emergence of these substructures. Based on simulations, a statistical parameter was associated with each substructure; it was interpreted as the extent to which this sub-structure is important in the generation of the network as it was empirically observed. Convergence of computations toward stable parameters signaled the capacity of the model to adjust to the observed data. Both endogenous (reflecting path dependency in the network) and exogenous effects (reflecting attribute-based effects) were represented in the specified models.

In Table 1, we present the structural parameters that we included in our model and that helped take into account the effect of relational substructures on the exchange of advice among entrepreneurs and control for the effect of the exogenous variables that we explored.
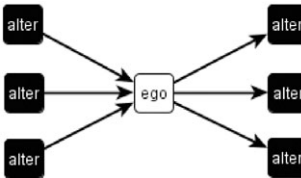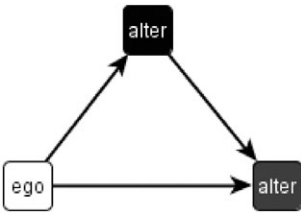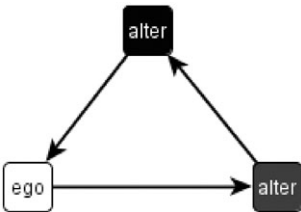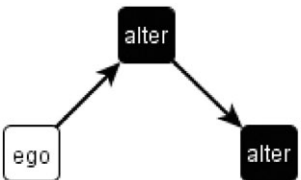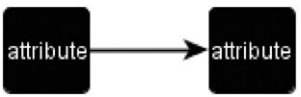
RESULTS

Personalization of Collaboration Ties with VCs
In order to test our first hypothesis on the added value of personal collaboration ties, we analyzed the effect of sharing the same type of relationship with VCs sitting on the board of the entrepreneurs' biotech companies on the exchange of knowledge among them. Results are presented in Table 2.

Model 1 (*co-affiliation by sharing a VC firm on the board*) explored the effect of co-affiliation to the same VC on exchange of knowledge among entrepreneurs regardless of whether the tie shared with the VC is personal or organizational. The value of the

TABLE 1. Definition of Structural Parameters Used to Model the Advice Network among Biotech Entrepreneurs

Observed density (fixed parameter): the observed density is the density of the network (the number of observed arcs divided by the number of potential arcs of the full network	
Reciprocity: it measures the probability for a relation to be a mutual one, in other words, the probability that two actors mutually choose each other.	
Alt-in-alt-out-star: it is an effect that controls for the behavior of actors in-degree and out-degree.	
Alternating transitive triangles: it is the probability for an actor to choose alters chosen by one of its other alter	
Alternating cyclic triangles: it is the probability for an actor to be chosen by an alter chosen by one of its chosen alters.	
Alternating independent two paths: it is the probability that two actors are linked by one or more alters.	
Exogenous effects of similarity: it is the probability for an actor to choose alters qualified with the same attribute.	

similarity effect of the dyadic variable representing this co-affiliation (*same co-affiliation VC*) is significant and positive. This means that biotech entrepreneurs who belong to the same VC portfolio of companies have a greater probability of exchanging advice than biotech entrepreneurs whose companies do not belong to the same portfolio. This result,

TABLE 2. Effect of Sharing a Personalized Collaboration Tie with a Venture Capital (VC) on the Exchange of Tacit Knowledge among French Biotech Entrepreneurs. Exponential Random Graph Models

Advice relationship among biotech entrepreneurs

Independent variables	Model 1 co-affiliation by sharing a VC firm in the board		Model 2 co-affiliation by sharing a personal tie with a VC in the board		Model 3 co-affiliation by sharing an organizational tie with a VC in the board		Model 4 co-affiliation by sharing a personal versus an organizational tie with a VC in the board	
	Coefficient (standard error)	t-Ratio convergence	Coefficient (standard error)	t-Ratio convergence	Coefficient (standard error)	t-Ratio convergence	Coefficient (standard error)	t-Ratio convergence
Structural effects								
Observed density (fixed parameter)	0.04		0.04		0.04		0.04	
Reciprocity	2.27 (0.16)	0.01	2.27 (0.16)	0.03	2.27 (0.16)	0.05	2.28 (0.16)	−0.01
Alternating-in-alternating-out-star	−0.71 (0.10)	−0.02	−0.71 (0.10)	−0.02	−0.71 (0.10)	0	−0.71 (0.10)	0.08
Alternating T-transitive	1.11 (0.05)	−0.01	1.11 (0.05)	0.05	1.11 (0.04)	0.03	1.11 (0.05)	−0.05
Alternating T-cyclic	−0.35 (0.04)	−0.02	−0.35 (0.04)	0.03	−0.35 (0.04)	0.01	−0.35 (0.04)	0.00
Alternating independent two paths	−0.03 (0.01)	−0.06	−0.03 (0.01)	0.02	−0.03 (0.01)	0.06	−0.03 (0.01)	−0.07
Exogenous effects of similarity								
Dyadic variables								
Same co-affiliation VC	0.17 (0.06)	0.04						
Same co-affiliation VC by *personal tie*			0.38 (0.12)	−0.05			0.39 (0.14)	−0.04
Same co-affiliation VC by *organizational tie*					0.17 (0.08)	−0.03	0.17 (0.09)	−0.06
Control variables								
Same professional origin	0.12 (0.03)	0.08	0.12 (0.03)	0.00	0.12 (0.03)	0.02	0.10 (0.03)	0.10
Same cluster	0.20 (0.04)	0.06	0.19 (0.03)	0.06	0.20 (0.03)	0.01	0.20 (0.03)	0.02

Note: Standard errors are in parentheses. Parameters at least twice as large as their standard errors are considered significant. All parameters have t < 0.1. We estimated these models with Pnet (http://www.sna.unimelb.edu.au/).

as well as all subsequent results, is significant controlling for sharing the same professional origin and the same geographical location, which are themselves positive and significant.

The next two models explored in more detail the kind of shared relationship with VCs sitting in the board of the biotech companies. Model 2 measured the effect on exchanges of knowledge among biotech entrepreneurs of sharing a personal tie with a VC. The value of the similarity effect associated with this variable (*same co-affiliation VC by personal tie*) is positive and significant. Model 3 measured the effect of sharing a nonpersonal tie with a VC, in other words, the effect of sharing the same VC but represented by two different persons in the boards of the two biotech companies. The value of the similarity effect associated with this variable (*same co-affiliation VC by organizational tie*) is also positive and significant. Model 4 disentangled the effect (and thus differentiates the added value) of each of the two co-affiliations. We included in this model the variable representing the pairs of entrepreneurs sharing the same personal relationship with the VC *and* the variable representing the pairs of entrepreneurs sharing the same investor but represented by different individuals. We observe that only the value of the effect associated with the variable representing the sharing of a personal tie with a VC is positive and significant. These results confirm our first hypothesis: the exchange of knowledge among entrepreneurs is significantly facilitated by sharing a personalized collaboration tie with the same VCs. Transitivity of collaboration ties at the interorganizational level is favored when these ties are personalized.

Friendship Ties with the VCs

Our second hypothesis explores the effect of a different kind of personal tie on sharing an advice tie: that of friendship ties. We controlled this effect with the dyadic variable representing collaboration ties shared with the VCs using financial rounds since 2001 (and not only financial rounds associated with a seat on the board of the company in 2008 as we did in the first analysis). Results are presented in Table 3.

In the first three models, we estimate the effect of these dyadic variables on a pairwise basis. We observe that sharing exclusively the same investor (*same historic VC*) is not associated with a greater probability of exchanging knowledge among entrepreneurs. This does not mean that collaboration ties do not have any effect. Model 2 shows that sharing the same investor with whom entrepreneurs also maintain a friendship tie is associated with a positive and significant similarity effect. However, Model 3 shows that the very strong added value of this shared multiplex tie on the probability that entrepreneurs will share tacit knowledge does not weaken the added value that friendship ties have on their own.

In model 4, we included all these dyadic variables in the same estimation. The trends described in the previous models are confirmed. Friendship ties and multiplex (collaboration combined with friendship) ties with the VCs increase the probability that entrepreneurs sharing these relationships will exchange advice. However, the simple co-affiliation to the same VC is not in itself a relationship that facilitates the transfer of knowledge among entrepreneurs. These results confirm our second

TABLE 3. Effect of Sharing a Personal Friendship Tie with a VC on the Exchange of Tacit Knowledge among French Biotech Entrepreneurs. Exponential Random Graph Models

Advice relationship between biotech entrepreneurs

Independent variables	Model 1		Model 2		Model 3		Model 4	
	Coefficient (standard error)	t-Ratio convergence	Coefficient (standard error)	t-Ratio convergence	Coefficient (standard error)	t-Ratio convergence	Coefficient (standard error)	t-Ratio convergence
Structural effects								
Observed density (fixed parameter)	0.04		0.04		0.04		0.04	
Reciprocity	2.29 (0.16)	-0.01	2.27 (0.15)	0.04	2.30 (0.16)	-0.00	2.30 (0.16)	-0.01
Alt-in-alt-out-star	-0.70 (0.09)	0.06	-0.70 (0.09)	-0.01	-0.68 (0.09)	-0.03	-0.68 (0.09)	-0.00
Alternating T-transitive	1.08 (0.04)	-0.09	1.09 (0.04)	0.00	1.05 (0.04)	-0.02	1.05 (0.04)	0.00
Alternating T-cyclic	-0.36 (0.038)	-0.05	-0.35 (0.03)	0.05	-0.38 (0.03)	-0.02	-0.38 (0.03)	-0.01
Alternating independent towpaths	-0.02 (0.01)	-0.02	-0.02 (0.01)	0.03	-0.02 (0.01)	-0.05	-0.02 (0.00)	-0.04
Exogenous effects of similarity								
Dyadic variables								
Same VC friend	0.31 (0.04)	-0.05	-0.16 (0.07)	-0.05	0.36 (0.05)	0.01	0.36 (0.05)	0.00
Same historic VC	0.01 (0.07)	-0.02					0.01 (0.09)	0.01
Same VC friend and historic VC			0.35 (0.04)	0.07	0.44 (0.06)	-0.05	0.43 (0.06)	0.03
Control variables								
Same professional origin	0.10 (0.03)	0.03	0.10 (0.02)	0.01	0.08 (0.03)	0.07	0.08 (0.03)	0.00
Same cluster	0.20 (0.03)	-0.06	0.20 (0.03)	-0.00	0.22 (0.04)	0.07	0.22 (0.04)	-0.00

Note: Standard errors are in parentheses. Parameters at least twice as large as their standard errors are considered significant. All parameters have t < 0.1. We estimated these models with Pnet (http://www.sna.unimelb.edu.au/).

ERG models.

hypothesis: friendship ties shared by two biotech entrepreneurs with the same VC, whether uniplex or multiplex, increase the probability that they will exchange tacit knowledge.

DISCUSSION AND CONCLUSION

Our analyses explore the added value of personal relationships within the framework of interorganizational networks. We showed that personalized collaboration ties with VCs facilitate the transfers of tacit knowledge among biotech entrepreneurs affiliated with these VCs. We also showed a similar effect when two entrepreneurs share a friendship tie, whether uniplex or multiplex (i.e., combined with a collaboration tie), with the same VC. We can thus confirm the importance of social embeddedness of interorganizational ties in a sector in which observation of personal ties has often been neglected.

These results suggest that in order to understand performance in the biotech industry, it is not enough to look at the contractual relationships among entrepreneurs; it is also necessary to observe personal ties that they share with investors, particularly VCs, and the effect of these personal ties on their sharing of knowledge. Thus, many studies focusing on the effects of institutional affiliations and geographical colocalization in this sector need to be supplemented with knowledge about the level of personalization of ties (i.e., nature and level of social embeddedness) that executives share with each other and with their financial partners.

Our results stress the importance of personal ties in the interorganizational learning process. Epistemic interdependencies related to exchange of tacit knowledge are embedded in, more or less, personalized ties. It is only by taking into account the level of personalization of these relationships that we can identify social niche strategies with which different types of actors make appropriate knowledge claims and decisions. We suggest that when the process of collective learning is characterized by the elaboration of complex bodies of knowledge in an uncertain context, strategies of personalization of relationships help mitigate opportunistic behavior, at least temporarily. Personalization of interorganizational ties allows actors to access resources, to participate in the construction of knowledge, and to be proactive in the co-orientation of activities and the definition of norms of exchange in this industrial sector.

These results also show the invisible nature of interdependencies at the interorganizational level. We learn that collaboration and friendship relationship are associated—similar to at the intraorganizational level—with transitive structures increasing the probability that two entrepreneurs will exchange knowledge. In this sense, the model that we developed shows concretely the social conditions under which knowledge externalities are generated. Based on critical work in economic geography (Boschma 2005), we propose to extend the notion of knowledge spillover to social and epistemic proximities—not only to geographical ones—that can be examined through the type and level of personalization of ties at the interorganizational level.

The next step in this line of research consists in representing systematically the social and organizational structures in which knowledge externalities are both created and distributed. Our results on the effects of personalization of relations on knowledge exchange, as well as work on professional and geographical homophily associated with collaboration ties, suggest that an important part of the value created by firms depends on the capacity of their members to embed their professional life in larger and multiplex relational contexts. It would now be useful to explore the extent to which companies encourage or require from their members that they participate in these social circles, and thus that they invest part of their private life and personal resources in the projects set up by the firm. If we want to account for the social dynamics creating knowledge externalities, it is convenient to consider the relational, social, and symbolic cost that actors must incur in order to capture these externalities. Observing the alignment of actors, both professional and personal, with an organizational project, observing the ways in which they mobilize their past affiliations, create friendships, or try to enrich professional relationships to access the resources that their company needs, all this will make these hidden costs visible, as well as the negative externalities that can be associated with the appropriation of the type of immaterial asset called distributed knowledge. This requires observation of multilevel social interdependencies that are generated by inter-individual and interorganizational networks.

With respect to collaborations between biotech firms and their investors, our results suggest that the role of VCs is not limited to allocation of financial resources. VCs facilitate exchanges of knowledge between members of their portfolios and thus the capacity of coordination and collective learning of their entrepreneurs. However, this contribution is not homogeneous. It concerns exclusively entrepreneurs with whom VCs decide to personalize their relationship. In that sense, this study should be complemented with an analysis focusing on how VCs choose and enrich their ties (i.e., transform them into multiplex ties) with entrepreneurs.

Finally, we would like to mention two additional limitations of this research. First, using ERGMs does not help with choosing between alternative theories. Results provided in this article account for social mechanisms associated with the occurrence of a knowledge exchange relationship, but they do not yet predict which of the four complementary hypotheses (professional homophily, geographical colocation, personalization of relations, and structural patterns) has the most explanatory power. Second, the static character of our relational data set (one-shot network measurement) does not allow us to explore the evolution of this advice network over time. It would be important to study this evolution in order to improve our knowledge of the strategies, allowing entrepreneurs to survive and/or succeed thanks to cooperation with their peers, often their competitors.

ACKNOWLEDGMENTS

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APPENDIX. Matrices Corresponding to the Advice Network (Dependent Variable) and Dyadic Variables (Independent Variables)

	Density	Degree average	1	2	3	4	5	6	7
1 Advice Network	0.43	7	—	—	—	—	—	—	—
2 Co-affiliation by sharing the VC on the board	0.04	7.26	0.03	—	—	—	—	—	—
3 Co-affiliation by sharing a personal tie with the VC on the board	0.01	2.18	0.03	0.54	—	—	—	—	—
4 Co-affiliation by sharing an organizational tie with the VC on the board	0.03	5.07	0.02	0.83	−0.02	—	—	—	—
5 Exclusively friend	0.1	17.08	0.13	−0.07	−0.04	−0.06	—	—	—
6 Friend and investor	0.04	7.14	0.11	0.32	0.16	0.28	−0.07	—	—
7 Exclusively investor	0.1	16.66	−0.01	0.39	0.22	0.32	−0.11	−0.07	—

Note: The two categorical control variables ("Same professional origin" and "Same cluster") are polytomic and were excluded from this table.